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NATIONAL DAM SAFETY PROGRAM. BIG FOUR MINE DAM (MO 30729), MISS--ETC(U)
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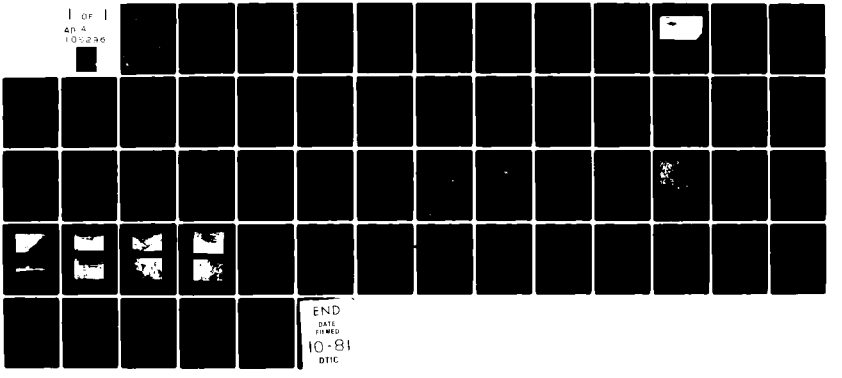

MISSISSIPPI-KASKASKIA-ST. LOUIS BASIN

LEVEL II

BS 1

BIG FOUR MINE DAM
WASHINGTON COUNTY. MISSOURI
MO 30729

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY INSPECTION

United States Army
Corps of Engineers
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St. Louis District

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PREPARED BY: U.S. ARMY ENGINEER DISTRICT. ST. LOUIS

FOR: STATE OF MISSOURI

SEPTEMBER 1980

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National Dam Safety Inspection. Big Four Mine Dam (MO 30729), Mississippi - Kaskaskia - St. Louis Basin, Washington County, Missouri. Phase I Inspection Report.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Dam Safety, Lake, Dam Inspection, Private Dams

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report was prepared under the National Program of Inspection of Non-Federal Dams. This report assesses the general condition of the dam with respect to safety, based on available data and on visual inspection, to determine if the dam poses hazards to human life or property.

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DEPARTMENT OF THE ARMY
ST. LOUIS DISTRICT, CORPS OF ENGINEERS
210 TUCKER BOULEVARD, NORTH
ST. LOUIS, MISSOURI 63101

REPLY TO ATTENTION OF

SUBJECT: Big Four Mine Dam (MO 30729)

This report presents the results of field inspection and evaluation of the Big Four Mine Dam (MO 30729). It was prepared under the National Program of Inspection of Non-Federal Dams.

SUMBITTED BY: SIGNED — 26 SEP 1980
Chief, Engineering Division — Date

APPROVED BY: SIGNED — 30 SEP 1980
Colonel, CE, District Engineer — Date

BIG FOUR MINE DAM

Washington County, Missouri

Missouri Inventory No. 30729

Phase I Inspection Report

National Dam Safety Program

Prepared by

Woodward-Clyde Consultants

Chicago, Illinois

Under Direction of

St Louis District, Corps of Engineers

for

Governor of Missouri

September 1980

PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams for Phase I Investigations. Copies of these guidelines may be obtained from the Office of the Chief of Engineers, Washington, D. C., 20314. The purpose of a Phase I investigation is not to provide a complete evaluation of the safety of the structure nor to provide a guarantee on its future integrity. Rather the purpose of the program is to identify potentially hazardous conditions to the extent they can be identified by a visual examination. The assessment of the general condition of the dam is based upon available data (if any) and visual inspections. Detailed investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify the need for more detailed studies. In view of the limited nature of the Phase I studies no assurance can be given that all deficiencies have been identified.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with any data which may be available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action removes the normal load on the structure, as well as the reservoir head along with seepage pressures, and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through frequent inspections can unsafe conditions be detected, so that corrective action can be taken. Likewise continued care and maintenance are necessary to minimize the possibility of development of unsafe conditions.

PHASE I REPORT
NATIONAL DAM SAFETY PROGRAM

Name of Dam	Big Four Mine Dam
State Located	Missouri
County Located	Washington
Stream	Unnamed Tributary of Calico Creek
Date of Inspection	26 June 1980

The Big Four Mine Dam (Mononame 562), Missouri Inventory Number 30729 was inspected by Mr L. M. Krazynski (geotechnical engineer), Mr R. Juyal (hydrologist), and Mr J. B. Stevens (geotechnical engineer).

The dam inspection was made following the guidelines presented in the "Recommended Guidelines for Safety Inspection of Dams". These guidelines were developed by the Chief of Engineers, U.S. Army, Washington, D.C., with the help of federal and state agencies, professional engineering organizations, and private engineers. The resulting guidelines represent a consensus of the engineering profession. They are intended to provide an expeditious identification, based on available data and a visual inspection, of those dams which may pose hazards to human life or property. In view of the limited scope of the study, no assurance can be given that all deficiencies have been identified.

This dam is classified as intermediate due to its 71 ft height and live storage of 1980 ac-ft.

The St Louis District, Corps of Engineers, has classified this dam as a high hazard dam; we concur with this classification. The potential damage zone, as determined by the St Louis District, Corps of Engineers, extends approximately 22 mi downstream. The community of Fletcher and several other occupied structures are located within the estimated damage zone.

The inspection and evaluation indicate that the dam is in poor condition. Specific deficiencies that were noted are very steep downstream slope, high potential for erosion of downstream toe by spillway outflow, high erodibility of the embankment materials and lack of maintenance and periodic inspections. Also deemed as a deficiency is the lack of any stability or seepage analyses.

Hydrologic/Hydraulic studies indicate the 1 percent probability-of-occurrence event (100-year flood) will not cause overtopping of the dam. These analyses also indicate that the dam will be overtopped for a hydrologic event which produces greater than 60 percent of the Probable Maximum Flood (PMF). The PMF is defined as the flood event that may be expected to occur from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in the region.

As remedial measures for the Big Four Dam, it is recommended that an additional study be made to evaluate and implement measures to increase spillway capacity to pass an appropriate portion of the PMF and to relocate the discharge channel away from the downstream toe of the dam. The problem of trash dumping in the vicinity of the discharge channel should also be addressed. Removal of trees and brush along the downstream toe is recommended to facilitate inspection, such as observation of changes in seepage flow, and evidence of slope instability. Removal of large trees should be done under the guidance of an engineer experienced in the design and construction of dams. Indiscriminate clearing of trees can jeopardize the stability of the dam. It is further recommended that seepage and stability analyses comparable to the guidelines be performed and be kept on record.

In addition, a program of periodic inspections should be implemented for the dam and appurtenant structures. This inspection should report needed maintenance requirements. Records of the inspections and maintenance should be kept.

It is suggested that corrective actions be initiated without undue delay.

WOODWARD-CLYDE CONSULTANTS

Richard G. Berggreen
Registered Geologist

Leonard M. Krazynski, P.E.
Vice President

OVERVIEW

BIG FOUR MINE DAM

MISSOURI INVENTORY NUMBER 30729

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
BIG FOUR MINE DAM - MISSOURI NO. 30729
TABLE OF CONTENTS

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
BIG FOUR MINE DAM, MISSOURI INVENTORY No. 30729

SECTION 1
PROJECT INFORMATION

1.1 General

a. **Authority.** The National Dam Inspection Act, Public Law 92-367, provides for a national inventory and inspection of dams throughout the United States. Pursuant to the above, an inspection was conducted of Big Four Mine Dam (Mononame 562), Missouri Inventory Number 30729.

b. **Purpose of inspection.** "The primary purpose of the Phase I investigation program is to identify expeditiously those dams which may pose hazards to human life or property... The Phase I investigation will develop an assessment of the general condition with respect to safety of the project based upon available data and a visual inspection, determine any need for emergency measures and conclude if additional studies, investigations, and analyses are necessary and warranted." (Chapter 3, Recommended Guidelines for Safety Inspection of Dams).

c. **Evaluation criteria.** The criteria used to evaluate the dam were established in the "Recommended Guidelines for Safety Inspection of Dams"; Engineering Regulation No. 1110-2-106 and Engineering Circular No. 1110-2-188; "National Program for Inspection of Non-Federal Dams", prepared by the Office of Chief of Engineers, Department of the Army, and "Hydrologic/Hydraulic Standards, Phase I Safety Inspection of Non-Federal Dams" prepared by the St Louis District, Corps of Engineers (SLD). These guidelines were developed with the help of several federal agencies and many state agencies, professional engineering organizations, and private engineers.

1.2 Description of Project

a. **Description of dam and appurtenances.** Big Four Mine Dam is an abandoned tailings dam. Although its construction and usage is typical of other barite tailings dams in the area, it is atypical of most dams constructed for the impoundment of water. The unique nature of these dams has a significant impact on their evaluation. A brief description of the general construction procedure and usage of Missouri barite tailings dams is necessary to understand the unique nature of these dams, and understand the differences between these dams and conventional water-retaining dams.

At the start of a barite mining operation in this area, a 10 to 20-ft high starter dam is usually first constructed across a natural stream channel. Generally the streams are intermittent so that construction is carried out in the dry. Trees and other vegetation are removed from the dam site and then a cutoff is often made to shallow bedrock. Locally obtained earth, usually a gravelly clay, is then placed to form the embankment. Compaction is limited to that provided by the equipment.

The barite ore is contained within the residual gravelly clay which is mined with earth-moving equipment. At the processing plant, the ore is washed to loosen and remove the soil. This water is obtained from the reservoir area behind the dam. The soil-laden, wash water (and water from other steps in the process) is then discharged into the reservoir. There the soil is deposited by sedimentation and the water recycled. Another step in the process removes the broken gravel-sized waste which is called "chat".

As the level of the fine tailings increases, the dam is raised. The usual method is to place chat on the dam crest by dumping. Then the chat is spread over the crest so that a relatively constant crest width is maintained as the dam is raised. Generally the crest centerline location is maintained constant. However, the crest centerline location may migrate upstream if there is insufficient chat available and downstream if an excessive quantity of chat is available. The latter is uncommon, because it is indicative of a poor ore deposit. Where the crest centerline migrates upstream chat deposits are being placed over the weak tailings deposits and the least stable configuration is

obtained. On the other hand, downstream migration of the centerline indicates subsequently placed chat deposits are being placed over previously placed chat deposits and the dam is more stable.

The dumping method of construction results in downstream slopes which are close to the natural angle of repose for the chat. They can be considered to be near a state of incipient failure.

A large quantity of water is required for a processing operation-on the order of 2000 to 5000 gal/min. Thus it has been the operators' practice to construct the dam so that all inflow to the reservoir is recycled in order to have sufficient water for the operation. The result is that formal spillways or regulating outlets are generally not constructed. In most cases a low point on or near the dam is provided for overflow, should the storage capacity be exceeded.

The fine tailings typically fill more than 80 percent of the total storage volume. This results from the operator's practice of maintaining only a 2 to 5 ft elevation differential between the level of the tailings and the dam crest. The differential is usually greater further away from the discharge point and also typically further away from the dam.

The geotechnical characteristics of the fine tailings are somewhat similar to recent lacustrine clay deposits. Where the tailings have been continuously submerged, they have a very soft consistency and high water contents. When evaporation causes the water level to recede and the tailings are exposed, a stiff crust forms as the tailings dry out. Below the crust, the tailings retain their soft consistency for long periods of time. The consistency is very gradually modified by a slow process of consolidation.

Big Four Mine Dam is representative of barite tailings dams. The embankment is composed of chat. The downstream slope is very steep and the upstream slope is covered by the fine tailings. There are no regulating outlets other than the ungated, earth-lined spillway. This spillway is located at the west

end of the dam and is unlined earth as is the downstream channel. The downstream channel passes along the downstream toe for about half the dam length.

b. **Location.** The dam is on an unnamed tributary of Calico Creek and about 3.5 mi E of Richwoods, Washington County, Missouri (see Fig. 1). It is located in Mineral Land Survey #177 about 2.3 mi east from Missouri Hwy 47, and is shown on the USGS Richwoods NE 7.5 min quadrangle map.

c. **Size classification.** The dam is classified as intermediate due to its 71 ft height and live storage volume of 1980 ac-ft. The intermediate size classification includes dams with heights greater than or equal to 40 ft but less than 100 ft, or dams with storage capacity greater than 1,000 ac-ft but less than 50,000 ac-ft.

d. **Hazard classification.** The SLD has classified this dam as a high hazard dam; we concur with this classification. The SLD estimated damage zone extends approximately 22 mi downstream. Located within this zone is the community of Fletcher and several other occupied structures.

e. **Ownership.** The dam is reportedly owned by NL Industries, Inc. whose local address is P.O. Box 218, Potosi, MO 63664. Correspondence should be addressed to the attention of Mr Clarence C. Houk, Manager, Missouri Barite Operations.

f. **Purpose of dam.** The dam was constructed to impound fine barite tailings and the process water. It is currently abandoned.

g. **Design and construction history.** The following information on the design and construction of the dam was provided by Mr Houk. No formal design was made. Construction followed local practice. A starter dam, 25 to 30-ft high was constructed in 1964. First a cutoff trench, 10 to 15 ft wide and 8 to 10 ft deep to rock was excavated. The trench was then backfilled with a red, gravelly clay (CH). Compaction of the backfill was performed with a

sheepsfoot roller. The starter dam was then constructed of the same material with 1(H): 1(V) slopes and a crest width of about 20 ft. The dam was continually raised with chat until cessation of operations in 1978.

h. **Normal operating procedures.** At the present time, mining activities have ceased and there are no operating procedures in effect.

1.3 Pertinent Data

a. **Drainage area.** Approximately 0.40 mi^2

b. **Discharge at damsite.**

Maximum known flood at damsite	Unknown
Warm water outlet at pool elevation	Not Applicable (N/A)
Diversion tunnel low pool outlet at pool elevation	N/A
Diversion tunnel outlet at pool elevation	N/A
Gated spillway capacity at pool elevation	N/A
Gated spillway capacity at maximum pool elevation	N/A
Ungated spillway capacity at maximum pool elevation	340 ft^3/sec at elev. 797.0 ft, MS
Total spillway capacity at maximum pool elevation	340 ft^3/sec at elev. 797.0 ft, MS

c. **Elevation (ft above MSL).**

Top of dam	797.0 to 801.5
Maximum pool-design surcharge	N/A
Full flood control pool	N/A
Recreation pool	N/A
Spillway crest (gated)	N/A
Upstream portal invert diversion tunnel	N/A
Downstream portal invert diversion tunnel	N/A
Streambed at centerline of dam	Unknown
Maximum tailwater	Unknown
Toe of dam at maximum section	727.9

d. **Reservoir.**

Length of maximum pool	2500 ft
Length of recreation pool	N/A
Length of flood control pool	N/A

e. **Storage (acre-feet).**

Recreation pool	N/A
Flood control pool	N/A
Design surcharge	N/A
Top of dam	1980

f. **Reservoir surface (acres).**

Top of dam	Approximately 104 at elevation 797
Maximum pool	Approximately 108 at elevation 798
Flood-control pool	N/A
Recreation pool	N/A
Spillway crest	92

g. **Dam.**

Type	Tailings
Length	2350 ft
Height	71 ft
Top width	25 to 40 ft
Side slopes	D/S, 1.6 (H) to 1(V); U/S, unknown
Zoning	Unknown (probably none)
Impervious core	Unknown (probably none)
Cutoff	Unknown (reportedly to shallow rock)
Grout curtain	Unknown (probably none)

h. **Diversion and regulating tunnel.**

Type	N/A
Length	N/A

Closure	N/A
Access	N/A
Regulating facilities	N/A

i. **Spillway.**

Type	Uncontrolled, earth partially lined with grass
Length of weir	N/A
Crest elevation	793.4 ft
Gates	N/A
U/S channel	N/A
D/S channel	Unlined earth

j. **Regulating outlets.** None

SECTION 2
ENGINEERING DATA

2.1 Design

No design drawings or data were found.

2.2 Construction

No construction records or data were found. Typical construction techniques are presented in Section 1.2a.

2.3 Operation

No records were found for reservoir water elevation or spillway discharge history. The dam is presently abandoned.

2.4 Evaluation

a. **Availability.** No data were available for review.

b. **Adequacy.** Insufficient data were available to determine the adequacy of the design.

Seepage and stability analyses comparable to the requirements of the guidelines are not on record. This is a deficiency that should be rectified. These analyses should be performed by an engineer experienced in the design and construction of dams. Further, these seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record.

c. **Validity.** Not applicable.

2.5 Project Geology

The dam site lies on the northern flank of the Ozark structural dome. The regional dip is to the north. The bedrock in the area is mapped as Cambrian Age Eminence and Potosi Dolomite Formations on the Geologic Map of Missouri (Fig. 4). The Potosi Formation typically contains an abundance of quartz druse characteristic of chert bearing formations. The Eminence Formation conformably overlies the Potosi Formation, and contains less quartz and chert.

The soil at the dam site is a dark red-brown, plastic residual clay (CH), characteristically developed on the Potosi Formation. It is locally overlain by a 1 to 5 ft thick silty loess soil profile. The area is mapped on the Missouri General Soils Map as Union-Goss-Gasconade-Peridge Association.

The Richwoods Fault zone lies approximately 2-1/2 miles south of the dam site and is mapped on the Structural Features Map of Missouri (1971) as discontinuous for approximately 19 mi, in a WNW-ESE direction. The Ditch Creek Fault System is located about 2 miles north of the site and is mapped on the Structural Features map as approximately 11 miles long, paralleling the Richwoods Fault zone. The Ditch Creek System is mapped as north side down; the Richwoods fault is mapped as north side up. The faults are likely Paleozoic in age and are not considered to be in a seismically active area.

SECTION 3
VISUAL INSPECTION

3.1 Findings

a. **General.** The Big Four Mine Dam was inspected with an owner's representative present for a portion of the time.

b. **Dam.** The embankment is composed of coarse tailings or "chat" (see Photos 1 and 2; Appendix A). This material (gravel, sandy gravel and sand with some boulders; GW, SW) is cohesionless and permeable and would likely be severely eroded if the dam were overtopped.

The downstream slope is 1.6 (H) to 1 (V) which is near the natural angle of repose for the chat. The upstream slope is covered by the tailings and therefore the geometry of the upstream slope is unknown. There is no erosion protection system on the upstream slope other than the coarse chat which is erodible under significant velocity flows (5 ft/sec) and heavy wave action. No studies were made to evaluate the relationship between possible wave action at this dam and size of slope material.

The vertical and horizontal alignment of the dam crest does not appear to be disturbed by deformations. No evidence of detrimental settlement, depressions, cracking, sinkholes or animal burrows were found during the inspection.

Clear seepage was noted flowing from many locations along the dam toe (see Photo 6; Appendix A). At each location, the quantity ranged from less than 1 to about 3 gal/min. From the toe, the seepage flowed into the downstream channel (see Photos 5 and 8; Appendix A). Aggregate volume of seepage was 30 to 50 gal/min. Observed seepage was not causing erosion or piping of the dam at the time of inspection.

The downstream slope is relatively free of vegetation (see Photo 7; Appendix A). Most trees and brush growing on the dam are located near the

toe. Removal of the trees and brush is recommended to facilitate observation of seepage. Some dumping of garbage and trash was noted near the county road in the general vicinity of the downstream discharge channel.

There was no evidence of prior overtopping or serious erosion.

c. **Appurtenant structures.** The spillway is uncontrolled and consists of an earthen channel partially lined with grass at the west end of the dam (see Photos 3 and 4; Appendix A). The soil appears to be moderately erodible. There are no observed conditions which would result in spillway blockage.

There are no low level regulating outlets at this dam.

d. **Reservoir area.** Approximately 60% of the reservoir area was above the water level at the time of inspection. The bottom of the reservoir is covered by fine tailings which are relatively impervious. There are several separator dikes in the reservoir which have crest elevations 2 to 5 ft below that of the dam crest. These dikes have caused differential bottom elevations within the reservoir ranging from 6 to over 15 ft. Their purpose is to retard the flow of tailings from one area of the reservoir to another.

The natural slopes around the reservoir area are relatively flat and indicated no signs of instability.

e. **Downstream channel.** The downstream channel is roughly triangular to trapezoidal in shape and is located in the close proximity to the downstream toe of the west half of the dam. It is in mostly unlined earth (see Photo 5; Appendix A). High flows in the channel would likely cause erosion of the dam toe.

3.2 Evaluation

The downstream slope is very steep and although no slides were observed, the slopes are considered to be close to incipient failure. Removal of material from the toe by

flow in the downstream channel would probably cause slides on the downstream slope. Relocation of the downstream discharge channel to the other side of the access road should be considered as a potential remedial measure.

The clear seepage noted at the time of our inspection is not considered to be a serious threat to the stability of the dam at this time. A portion of the clear seepage may be a result of consolidation of the fine-grained tailings. The amount and nature of the seepage should be monitored by future inspections.

Removal of trees and brush on the slope and at the toe of the dam is recommended to facilitate observation of seepage and signs of possible distress. Removal of large trees should be done under the guidance of an engineer experienced in the design and construction of dams. Indiscriminate clearing could jeopardize the stability of the dam.

Flows greater than about 5 ft/sec in the spillway may cause erosion of the spillway and of the west end of the dam. This condition should be evaluated by further study.

There are no obstructions at present in the downstream channel which would reduce its capacity to below that of the spillway. The dumping of trash in the vicinity of the channel should be discontinued, so that no future obstructions are created.

SECTION 4
OPERATIONAL PROCEDURES

4.1 Procedures

So far as could be determined there are no operational procedures for this dam. The water level is controlled by the crest of the spillway.

4.2 Maintenance of Dam

No records of maintenance on this facility were available.

4.3 Maintenance of Operating Facilities

There are no operating facilities at this dam.

4.4 Descriptions of Any Warning System in Effect

The inspection did not find any warning system in effect at this facility.

4.5 Evaluation

There are apparently no maintenance or operational procedures in effect. The lack of regular maintenance and periodic inspection is considered a deficiency.

The feasibility of a practical warning system should be evaluated to provide early warning to downstream residents should potentially hazardous conditions develop during periods of heavy precipitation.

SECTION 5
HYDRAULIC/HYDROLOGIC

5.1 Evaluation of Features

a. **Design data.** No hydrologic or hydraulic information was available for evaluation of the dam. Pertinent dimensions of the dam and reservoir were surveyed on 8 July 1980, measured during the field inspection or estimated from topographic mapping. The map used in the analysis was an advanced print of the USGS Richwoods NE 7.5 minute quadrangle map.

b. **Experience data.** No recorded rainfall, runoff, discharge or pool stage data were available for this reservoir or watershed. No evidence of prior overtopping was observed.

c. **Visual observations.**

1. Watershed. The watershed is predominantly rural and thinly wooded. Much of the area has been previously strip-mined and has been reclaimed by nature to varying degrees.

2. Reservoir. The reservoir was approximately 60 percent above water at the time of inspection. A baffle dike separates the clear water from much of the above-water tailings as seen in the Overview Photo. The reservoir is approximately 40 percent of the total watershed area of 0.40 mi^2.

3. Spillway. The spillway is located at the right abutment of the dam as the viewer faces downstream. It is approximately triangular in shape and is earth-lined with some grass. Sideslopes are approximately 12(H): 1(V) on the east side and about 5.3(H): 1(V) on the west. There were no conditions noted that would lead to spillway blockage during periods of high outflow.

4. Downstream channel. The downstream channel is roughly triangular in shape to trapezoidal. It is lined primarily with soil but also with grass and low

lying brush. Due to the relatively steep gradient of the channel supercritical flow is a possibility which will result in significant erosion of the channel.

5. Seepage. The magnitude of seepage is not hydraulically significant to the overtopping potential of this dam.

d. **Overtopping potential.**

The hydrologic/hydraulic analyses indicate that the 1 percent probability-of-occurrence event will not overtop the dam. These analyses also indicate that the dam will be overtopped for a hydrologic event which produces greater than 60 percent of the Probable Maximum Flood (PMF). The PMF is defined as the flood event that may be expected to occur from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in the region. The following overtopping data for selected precipitation events were computed for the dam, assuming no erosion of the spillway or dam embankment:

Percent PMF	Max. Reservoir W.S. Elev.	Max. Depth over Dam, ft	Max. Outflow, ft^3/sec	Duration of Overtopping, hrs
50	796.4	0	215	0
100	798.1	1.1	925	5.83

As the embankment material is considered to be highly erodible, overtopping could rapidly lead to failure of the dam. However, as the spillway and the point of overtopping are located at the right abutment and not near the maximum dam section, a sudden dam failure is not expected. The high outflow will deepen and widen the spillway by erosion therefore increasing outflow capacity.

The soil at the spillway is considered to be moderately erodible. Mean channel velocities greater than about 5 ft/sec may cause significant erosion of the spillway and downstream channel and of the west end and downstream toe of the dam. A more detailed evaluation of this condition is recommended.

SECTION 6
STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

a. **Visual observations.** The visual inspection of Big Four Mine Dam revealed no evidence of horizontal or vertical displacement of the dam crest alignment. Cracking, detrimental settlement, slides, depressions or other signs of instability were not observed.

b. **Design and construction data.** No design or construction data relating to the stability of the dam were available. Seepage and stability analyses comparable to the requirements of the guidelines are not on record. This is a deficiency which should be corrected.

c. **Operating records.** No operating records were available.

d. **Post construction changes.** The lack of drawings or construction reports precludes identification of post construction changes. However, no obvious changes were observed.

e. **Seismic stability.** The dam is in Seismic Zone 2, to which the guidelines assign a moderate damage potential. Since no static stability analysis is available for review, the seismic stability cannot be evaluated. However, as the tailings are fine-grained saturated materials and the embankment consists of loose, granular material, it is expected that substantial deformation or failure of the embankment could occur in the event of a severe seismic event.

SECTION 7
ASSESSMENT/REMEDIAL MEASURES

7.1 Dam Assessment

a. **Safety.** Based on the visual inspection, Big Four Mine Dam is judged to be in poor condition. The very steep downstream slope, the possiblity of erosion of the downstream toe of the dam by spillway outflow, the high erodibility of the embankment materials, and lack of maintenance and periodic inspections are the primary reasons for this judgment.

As a consequence of the widely-used construction procedure, the downstream slopes of tailings dams are placed at the angle of natural repose for the "chat" material. This results in slopes that are very steep and exist in a state close to incipient failure with safety factors close to 1.0. These slopes will only remain stable if they are protected against potential harmful changes, among which are:

1. Overtopping by water
2. Higher pore pressures (or seepage forces)
3. Undercutting of the toe of the slope by erosion or mining activity
4. Increase in the height of the slope (applicable to active operations)
5. Harmful effects of vegetation (particularly tree roots)
6. Liquefaction (such as may result from a seismic event).

The first five changes are subject to control by owners and operators and must receive careful attention in order to maintain stable and safe dam embankments. The sixth influence represents a risk the magnitude of which is not well understood without further study.

The risk of dam failure decreases over a period of time due to consolidation of the impounded tailings. If no tailings are added to the impoundment for a period of time (as if the facility was abandoned), they consolidate and settle and very slowly gain internal strength.

In overall aspect, consolidated tailings are less likely to flow should the embankment fail. However, the gain of strength due to consolidation is a very slow process and for purposes of this study the tailings were of necessity considered as behaving like a fluid.

b. **Adequacy of information.** The lack of design data or stability and seepage analyses for the dam comparable to those recommended in the guidelines precludes an evaluation of the structural and seismic stability of the dam. This is considered a deficiency.

c. **Urgency.** The deficiencies described in this report could affect the safety of the dam. Corrective actions should be initiated without undue delay.

d. **Necessity for Phase II.** In accordance with the Recommended Guidelines for Safety Inspection of Dams, the subject investigation was a minimum study. This study revealed that additional in-depth investigations are needed to complete the assessment of the safety of the dam. Those investigations which should be performed without undue delay are described in Section 7.2.b. It is our understanding from discussions with the SLD that any additional investigations are the responsibility of the owner.

7.2 Remedial Measures

a. **Alternatives.** There are several general options which may be considered to reduce the possibility of dam failure or to diminish the harmful consequences of such a failure. Some of these options are:

1. Remove the dam, or breach it to prevent storage of water.

2. Increase the height of dam and/or spillway size to pass the probable maximum flood without overtopping the dam.

3. Purchase downstream land that would be adversely impacted by dam failure and restrict human occupancy.

4. Enhance the stability of the dam to permit overtopping by the probable maximum flood without failure.

5. Provide a highly reliable flood warning system (generally does not prevent damage but avoids loss of life).

b. **Recommendations.** Based on our inspection of Big Four Mine Dam, it is recommended that further study be conducted to evaluate as a minimum:

1. What spillway capacity should be provided and in what manner, taking into consideration the high potential erodibility of the embankment materials in the event of overtopping. The potential for erosion during periods of heavy flow within the earth-lined spillway, the adjacent embankment at the end of the dam and in the downstream channel along the toe of the dam should be examined. Relocation of the channel to the other side of the County road should be considered.

2. Evaluation of the risks involved in the current practice of trash dumping in the vicinity of the discharge channel and implementation of an effective remedial action.

3. Removal of trees and brush on the downstream face and at the toe of the dam to facilitate inspection of seepage and any evidence of slope instability. Removal of large trees should be done under the guidance of an engineer experienced in the design and construction of dams. Indiscriminate clearing could jeopardize the stability of the dam.

4. Analysis of the static and seismic stability of the dam and of the effects of seepage on the stability of the dam, in accordance with the requirements of the guidelines.

All remedial measures should be performed under the guidance of an engineer experienced in the design and construction of dams. It is recommended that the owner take action on these items without undue delay.

c. **O & M procedures.** A program of periodic inspections is recommended for the Big Four Mine Dam. This program should include, but not be limited to:

1. Inspection of seepage areas to identify increases in volume of seepage or turbidity (soil) in the seepage water.

2. Inspection of slopes to identify evidence of slope instability such as cracking or slumping of the embankment.

Records should be kept of the inspections and any required maintenance. All remedial measures should be performed under the guidance of an engineer experienced in the design and construction of dams.

The evaluation of a practical and effective warning system is recommended to alert downstream traffic and residents should hazardous conditions develop at this dam.

REFERENCES

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McCracken, Mary H., 1971, Structural Features Map of Missouri: Missouri Geological Survey, Scale 1:500,000.

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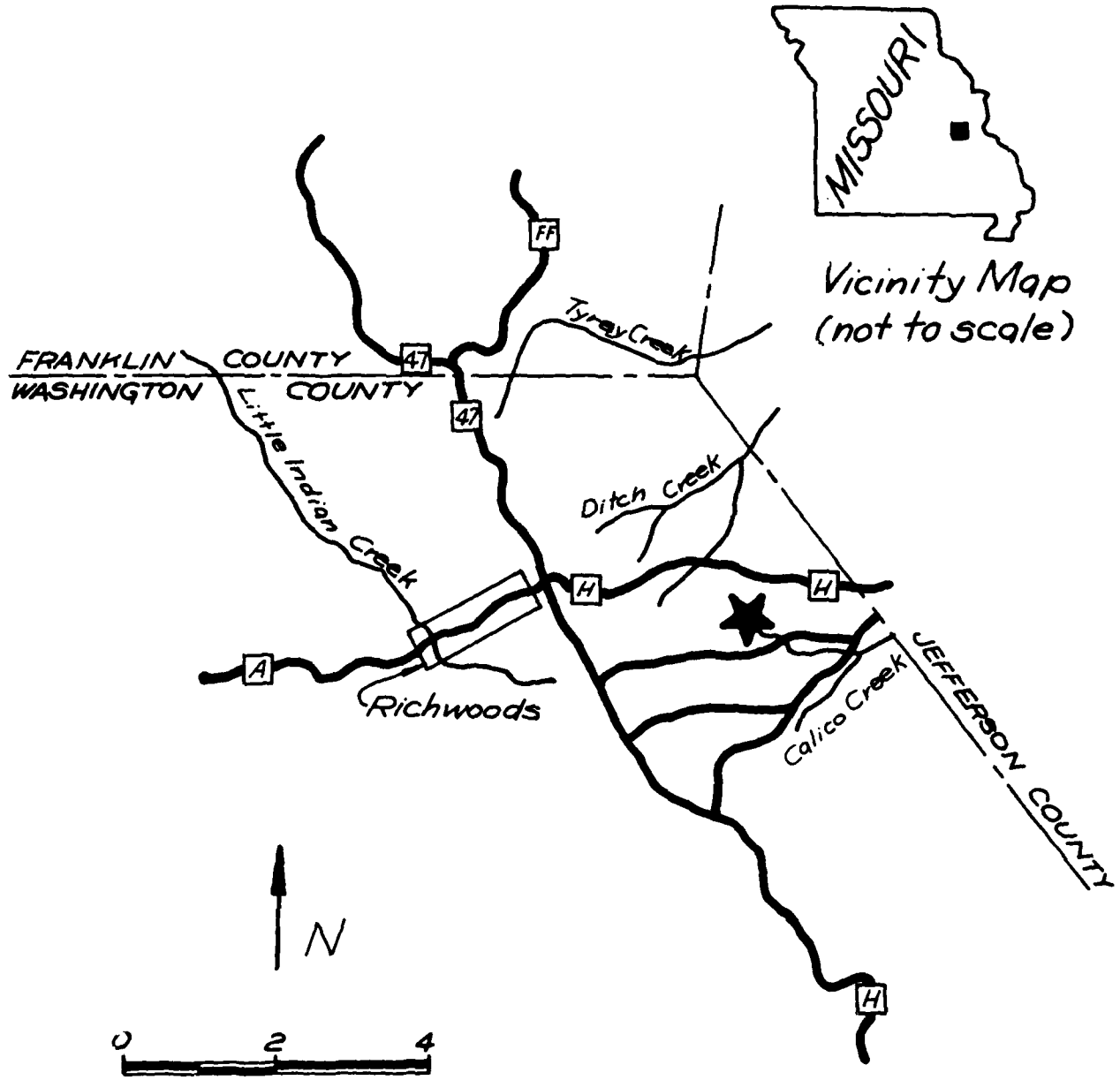
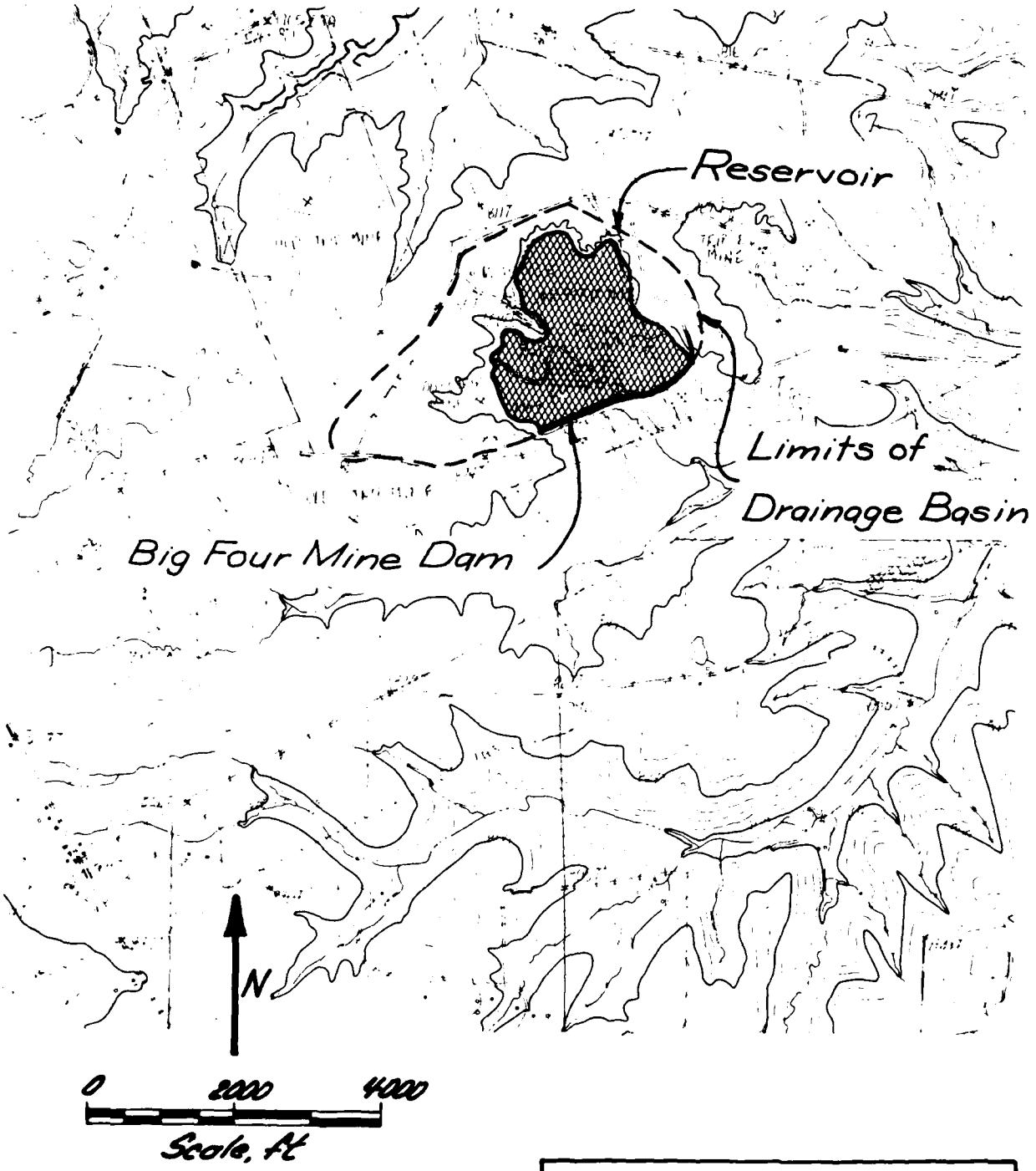
US Soil Conservation Service, 1971, "National Engineering Handbook," Section 4, Hydrology, 1971.



Legend

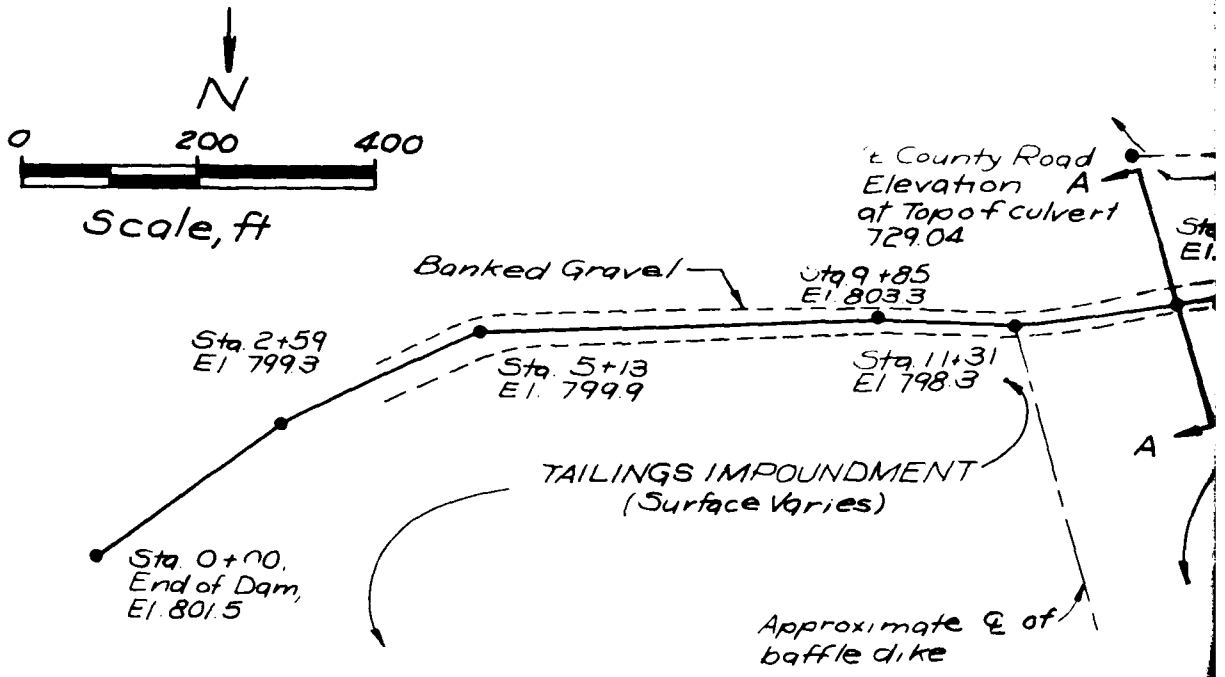
- County Line
- State highway and Route No.
- River or Creek
- City or Town
- Project location

SITE LOCATION MAP	
BIG FOUR MINE DAM	
MO 30728	Fig. 1

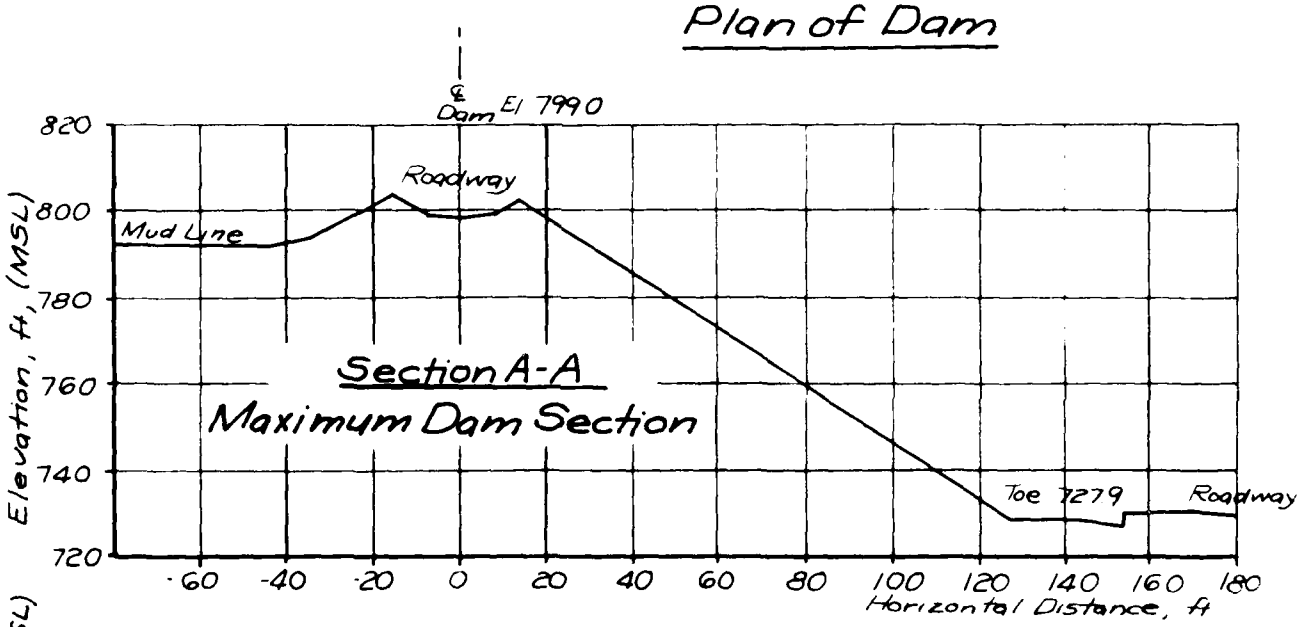


1. Topography from U.S.G.S. Richwoods NE 7½ minute quadrangle map.

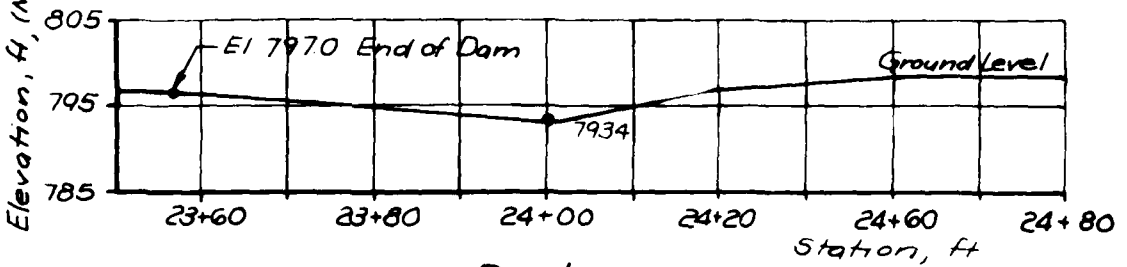
DRAINAGE BASIN AND SITE TOPOGRAPHY	
BIG FOUR MINE DAM	
MO 30729	Fig. 2



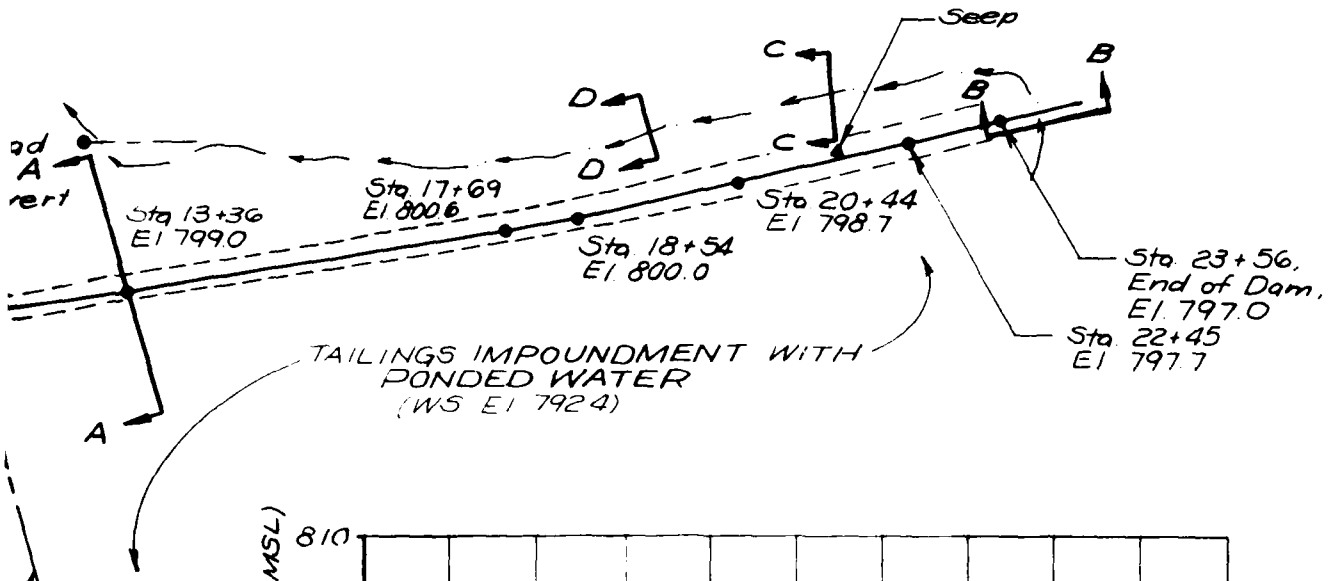
Plan of Dam

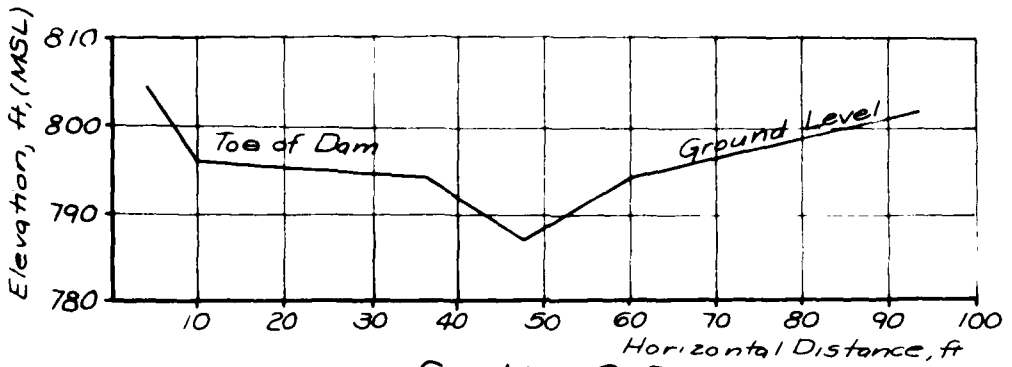


Section A-A
Maximum Dam Section

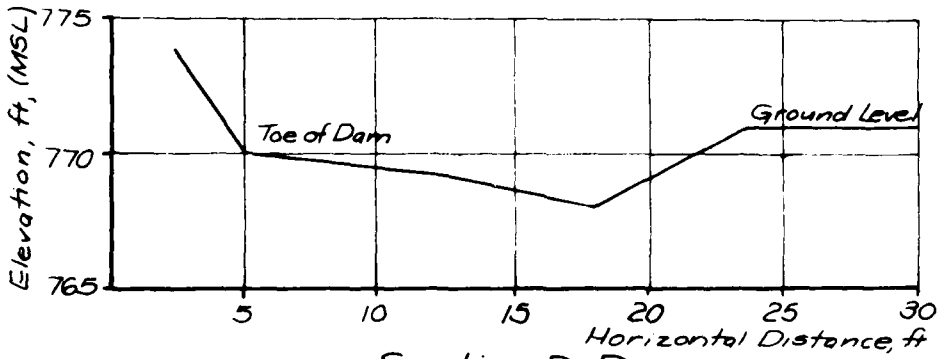


Section B-B
Spillway





Section C-C
Discharge Channel



Section D-D
Discharge Channel

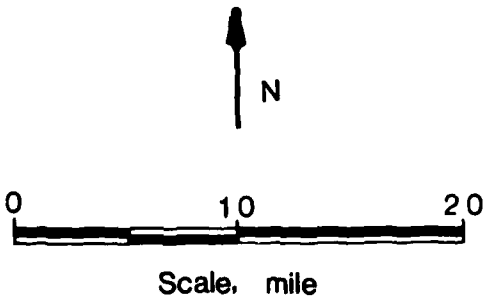
Roadway

160

Legend:

- Limits of banked gravel, discontinuous
- Downstream channel drainage path

PLAN AND SECTION OF DAM AND SECTIONS OF SPILLWAY AND DOWNSTREAM CHANNEL	
BIG FOUR MINE DAM	
MO 30729	Fig. 3



Legend

Roubidoux Formation

Gasconade Dolomite
Gunter Sandstone Member

Eminence *Dolomite*

Potosi Dolomite

Derby-Doerun Dolomite

Davis Formation

Bonneterre Formation
Whetstone Creek Member
Sullivan Siltstone Member

Reagan Sandstone
(subsurface, western Missouri)

Lamotte Sandstone

Diabase (dikes and sills)

St. Francois Mountains Intrusive Suite

St. Francois Mountains Volcanic Supergroup

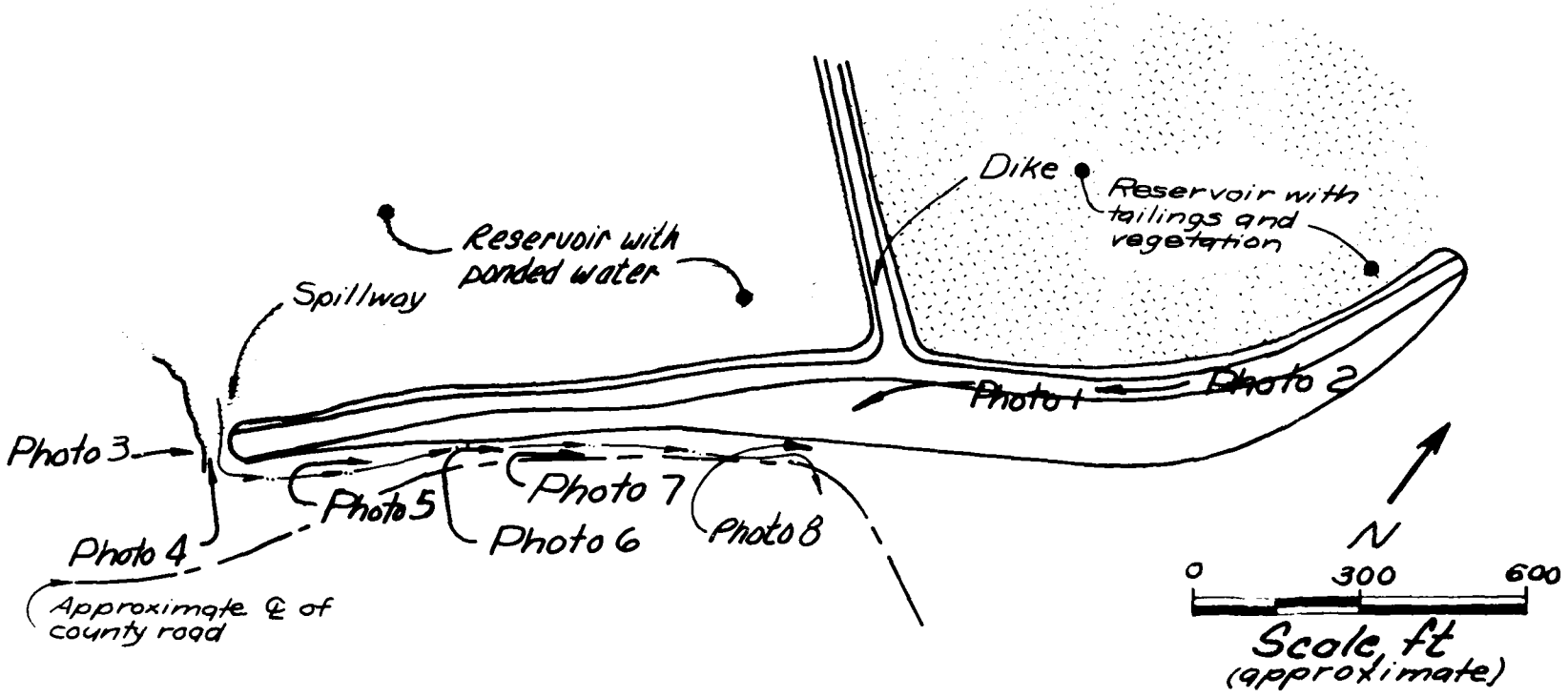
REGIONAL GEOLOGIC MAP

BIG FOUR MINE DAM

MO 30729 | Fig. 4

APPENDIX A

Photographs



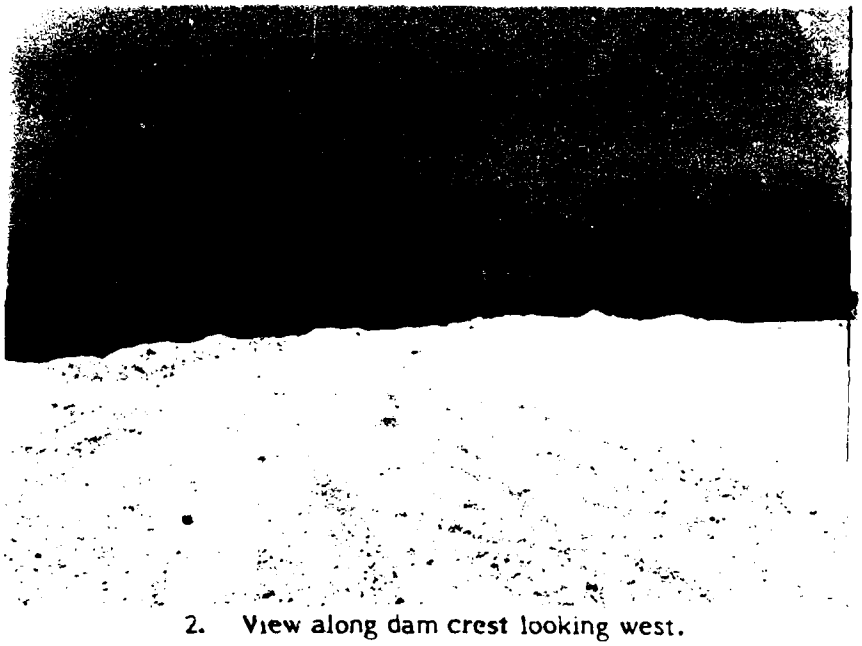
Legend

Downstream channel drainage path

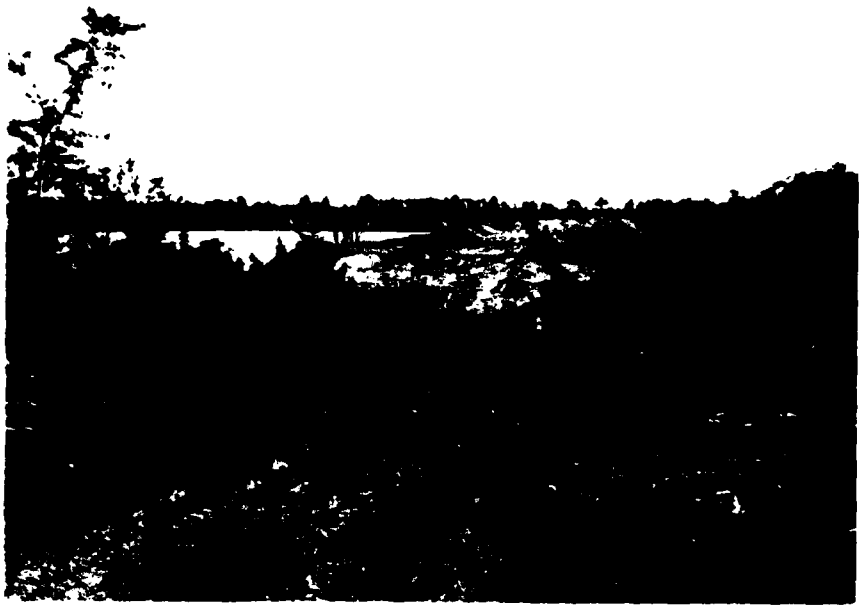
PHOTO LOCATION SKETCH

BIG FOUR MINE DAM	
MO 30729	Fig. A-1

1. View of downstream slope of maximum section. Discharge channel between road and dam toe.

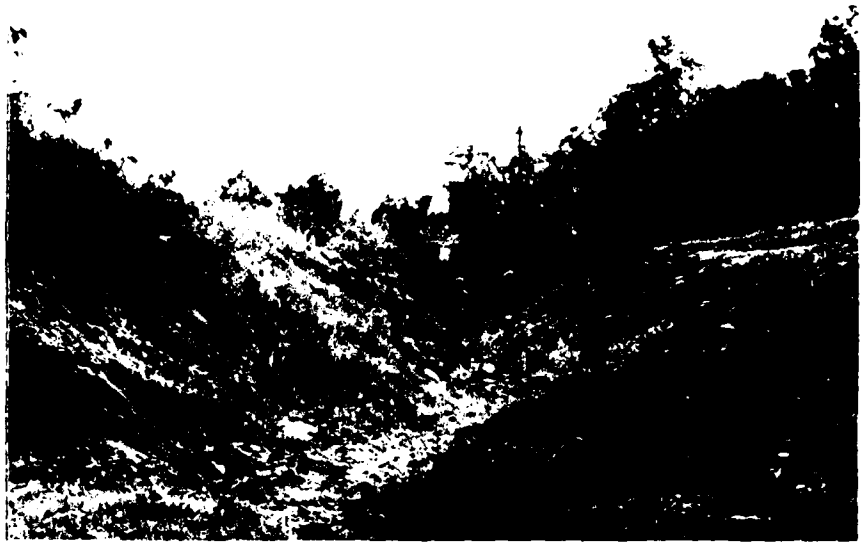


2. View along dam crest looking west.



3. View of dam crest from west abutment. Spillway in center.

4. Spillway entrance looking upstream.



5. Discharge channel about 250 feet from spillway. Looking downstream.

6. Clear seepage from toe of about 2-4 gallons per minute. Typical of many seeps observed. Note discharge channel in background.

7. Downstream slope looking northeast. Spillway discharge channel lies between road and toe of dam.

8. Discharge channel near maximum dam section. Flow is from seepage. Observer is standing on dam toe.

APPENDIX B

Hydraulic/Hydrologic Data and Analyses

APPENDIX B

Hydraulic/Hydrologic Analyses

B.1 Procedures

a. **General.** The hydraulic/hydrologic analyses were performed using the "HEC-1, Dam Safety Version (1 Apr 80)" computer program. Inflow hydrographs were developed by applying various precipitation events to a synthetic unit hydrograph. The inflow hydrographs, thus obtained, were then routed through the reservoir and appurtenant structures by the modified Puls reservoir routing method used in the HEC-1 program to determine overtopping potential.

b. **Precipitation events.** Various percentages including 100 percent of the Probable Maximum Precipitation (PMP) and the 1 and 10 percent probability-of-occurrence events were used in the analyses. The PMP was determined from Hydrometeorological Report #33. The 1 and 10 percent probability-of-occurrence events were provided by SLD for the station at Sullivan.

c. **Unit hydrograph.** The Soil Conservation Service (SCS) unit hydrograph (SCS, 1971) for a storm duration of 24 hrs was used to develop the inflow hydrograph. The unit hydrograph was divided into 5 min increments.

d. **Infiltration losses.** The SCS curve number (CN) method was used to compute infiltration losses. Curve numbers were selected on the basis of antecedent moisture conditions in accordance with the guidelines, present land usage and hydrologic soil group of the soils in the drainage basin. Where more than one soil group was present, the group giving the highest CN was used for the entire basin.

e. **Lag time.** Lag time was computed by the SCS method (National Engineering Handbook, Equation 15-4).

B.2 Pertinent Data

a. **Drainage area:** 0.40 mi^2

b. **Lag time:** 0.4 hrs

c. **Hydrologic soil group:** D

d. **SCS curve numbers.**

1. For PMF: 93 (AMC III)
2. For 1 and 10 percent probability-of-occurrence events: 89 (AMC II)

e. **Storage.** Elevation-area data were developed by planimetering areas at various elevation contours on the USGS Richwoods NE 7.5-minute quadrangle map. The data were entered on the $A and $E cards so that the HEC-1 program could compute storage volumes.

f. **Outflow capacity.** The elevation - discharge relationship was developed from cross-sections of the spillway and downstream channel using the HEC-2 step backwater profile program and entered on the Y4 and Y5 cards for the HEC-1 program.

g. **Outflow over crest.** As the profile of the dam crest is irregular, flow over the crest cannot be determined by conventional weir formulas. Crest length-elevation data and hydraulic constraints for the crest were entered on $D, $L and $V cards.

h. **Reservoir elevations.** For all fractions of the PMF, the starting reservoir elevation was the spillway crest elevation of 793.4 ft. For the 1 and 10 percent probability-of-occurrence events, the starting reservoir elevation also was 793.4 ft.

B.3 Results

The results of the analyses as well as the input values to the HEC-1 and HEC-2 programs follow in this Appendix. Only the results summaries are included, not the intermediate output. Complete copies of the HEC-1 and HEC-2 output are available in our office.

THIS RUN EXECUTED 25 JUL 89 12.42.40

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**********************************************
 HEC2 RELEASE DATED NOV 76 UPDATED APRI 1980
 ERROR CODE = 01.02.03.04
 MODIFICATION - 51.52.53.54
**********************************************

T1      BIG FOUR MINE DAM NO. 30729
T2
T3      SLOPE AREA METHOD FOR STARTING WATER SURFACE ELEVATION

J1  ICHECK     INQ       NINV      IDIM      STRT      METRIC    HVINS     Q         WSEL      FQ
        -0.       2.       -0.       -0.    .056000      -0.       -0.       -0.    781.500     -0.

J2  NPROF     IPLOT     PRFVS     XSECV     XSECH      FN       ALLOC      INW       CHNIM     ITRACE
        1.000     -3.    -1.000      -0.       -0.       -0.       -0.       -0.       -0.       -0.

J3  VARIABLE CODES FOR SUMMARY PRINTOUT
       98.000    43.000     1.000     3.000    26.000     -0.       -0.       -0.       -0.       -0.

J4  CPRNT     NUMSEC                          **********REQUESTED SECTION NUMBERS********
      -10.000   -10.000     -0.       -0.       -0.       -0.       -0.       -0.       -0.       -0.
NC      .000      .000      .000      .100      .300      -0.       -0.       -0.       -0.       -0.
NC     5.000    10.000    50.000   100.000   200.000   400.000   600.000   800.000  1000.000  1500.000

X1      1.000     5.000  1000.000  1394.400      -0.       -0.       -0.       -0.       -0.       -0.
GR    789.600  1000.000   788.500  1010.800   780.200  1031.600   784.100  1040.600   788.500  1058.400

X1      2.000     5.000  1000.000  1064.100   127.300   127.300   127.300      -0.       -0.       -0.
GR    790.400  1000.000   794.400  1018.500   796.700  1031.300   794.300  1042.400   795.900  1060.100

X1      3.000     5.000  1000.000  1045.100   199.000   199.000   199.300      -0.       -0.       -0.
GR    798.503  1000.000   796.600  1022.800   793.400  1040.300   795.600  1062.700   797.000  1085.100
ES      -0.       -0.       -0.       -0.       -0.       -0.       -0.       -0.       -0.       -0.
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HEC-2
Big Four Mine Dam
MO ID No 30729
B3

THIS RUN EXECUTED 25 JUL 80 12.52.40

HEC2 RELEASE DATED NOV 76 UPDATED APRI 1980
ERROR CODE = 01.02.03.04
MODIFICATION - 51.51.52.53.54

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
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J2	NPROF	IPLOT	PRFVS	XSECV	XSECH	FN	ALLOC	IRH	CHNIM	ITRACE
	2.000	-0.	-1.000	-0.	-0.	-0.	-0.	-0.	-0.	-0.

THIS RUN EXECUTED 25 JUL 80 12.52.40

HEC2 RELEASE DATED NOV 76 UPDATED APRI 1980
ERROR CODE = 01.02.03.04
MODIFICATION - 51.51.52.53.54

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
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J2	NPROF	IPLOT	PRFVS	XSECV	XSECH	FN	ALLOC	IRH	CHNIM	ITRACE
	3.000	-0.	-1.000	-0.	-0.	-0.	-0.	-0.	-0.	-0.

HEC-2
Big Four Mine Dam
MO ID No 30729
B4

HEC2 RELEASE DATED NOV 76 UPDATED APRI 1980
ERROR CORR - 31.32.33.34
MODIFICATION - 51.51.52.53.54

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
	-10.	5.	-0.	-0.	.056000	-0.	-0.	-0.	744.500	-0.
J2	NPROF	IPLOT	PRFVS	XSECV	XSECH	FN	ALLOC	IRH	CHNIM	ITRACE
	5.000	-0.	-1.000	-0.	-0.	-0.	-0.	-0.	-0.	-0.

HEC2 RELEASE DATED NOV 76 UPDATED APRI 1980
ERROR CORR - 31.32.33.34
MODIFICATION - 51.51.52.53.54

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
	-10.	6.	-0.	-0.	.056000	-0.	-0.	-0.	746.000	-0.
J2	NPROF	IPLOT	PRFVS	XSECV	XSECH	FN	ALLOC	IRH	CHNIM	ITRACE
	5.000	-0.	-1.000	-0.	-0.	-0.	-0.	-0.	-0.	-0.

HEC-2
Big Four Mine Dam
MO ID No 30729
B5

THIS RUN EXECUTED 25 JUL 80 12.52.41

HEC2 RELEASE DATED NOV 76 UPDATED APRI 1980
ERROR CODE = 01.02.03.04
ADDIFICATION - 51.51.52.53.54

J1
J2
J3

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
	-10.	7.	-0.	-0.	.056003	-0.	-0.	-0.	747.000	-0.

J2	NPNUP	IPLOT	PREVS	XSECV	XSECH	FN	ALLOC	IBW	CHNIM	ITRAC
	0.000	-0.	-1.000	-0.	-0.	-0.	-0.	-0.	-0.	-0.

THIS RUN EXECUTED 25 JUL 80 12.52.41

HEC2 RELEASE DATED NOV 76 UPDATED APRI 1980
ERROR CODE = 01.02.03.04
ADDIFICATION - 51.51.52.53.54

J1
J2
J3

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
	-10.	5.	-0.	-0.	.056000	-0.	-0.	-0.	747.500	-0.

J2	NPNUP	IPLOT	PREVS	XSECV	XSECH	FN	ALLOC	IBW	CHNIM	ITRAC-
	1.000	-0.	-1.000	-0.	-0.	-0.	-0.	-0.	-0.	-0.

HEC-2
Big Four Mine Dam
MO ID No 30729
B6

THIS RUN EXECUTED 25 JUL 90 12.52.41

HEC2 RELEASE DATED NOV 76 UPDATED APRI 1990
ERROR CODE = 31.32.33.34
MODIFICATION = 51.51.52.53.54

T1
T2
T3

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
	-10.	9.	-0.	-0.	.056000	-1.	-0.	-0.	738.000	-0.
J2	NPROF	IPLOT	PRFVS	XSECV	XSECH	FN	ALLOC	IPW	CHNIM	ITRACE
	19.000	-0.	-1.000	-0.	-0.	-0.	-0.	-0.	-0.	-0.

HEC-2
Big Four Mine Dam
MO ID No 30729
B7

THIS RUN EXECUTED 25 JUL 80 12.52.41

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**********************************************
  HEC2 RELEASE DATED NOV 76 UPDATED APRI 1980
  ERROR CODE -  01.02.03.04
  MODIFICATION -  50.51.52.53.54
**********************************************
```

NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

SLOPE AREA METHOD FOR ST

SUMMARY PRINTOUT

	SECNO	Q	CWSEL	EG	VCH
	1.000	10.00	781.27	781.48	3.55
	1.000	50.00	782.16	782.62	5.47
*	1.000	100.00	782.74	783.39	6.44
*	1.000	200.00	783.55	784.41	7.43
*	1.000	400.00	784.65	785.75	8.34
*	1.000	600.00	785.42	786.68	9.00
*	1.000	800.00	786.02	787.42	9.48
*	1.000	1000.00	786.54	788.05	9.87
	2.000	10.00	789.02	789.23	3.74
	2.000	50.00	789.07	789.58	5.70
	2.000	100.00	789.79	790.48	6.89
*	2.000	200.00	790.67	791.70	8.12
*	2.000	400.00	791.94	793.29	9.32
*	2.000	600.00	792.87	794.45	10.11
*	2.000	800.00	793.61	795.40	10.72
*	2.000	1000.00	794.56	796.21	10.32
	3.000	10.00	794.21	794.27	1.49
	3.000	50.00	794.94	795.06	2.76
	3.000	100.00	795.45	795.60	3.12
	3.000	200.00	796.16	796.34	3.43
	3.000	400.00	797.07	797.28	3.64
	3.000	500.00	797.73	797.96	3.85
	3.000	600.00	798.31	798.56	3.98
	3.000	1000.00	798.80	799.06	4.12

HEC-2 Output Summary
Big Four Mine Dam
MO ID No 30729
B8

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**********
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION  JULY 1978
 LAST MODIFICATION  01 APR 80
**********
    1          A1   BIG FOUR MINE DAM NO. 30729
    2          A2   WOODWARD-CLYDE CONSULTANTS, HOUSTON, TEXAS JOB NO. 79CH009
    3          A3   PROBABLE MAXIMUM FLOW(PMF) RATIO ANALYSIS
    4          B   288       0       5      -0      -0      -0      -0      -0      -0      -0
    5          B1    5
    6          J     1       4       1
    7          J1  .25     .50     .75     1.0
    8          K     0   LAKE                                                  1
    9          K1     INFLOW HYDROGRAPH CALCULATION
   10          H     1       2      .4                              1
   11          P     0      26.    102.    120.    130.
   12          T                                                   -1     -93              .4
   13          H2            .4
   14          X    -1    -.05       5
   15          K     1     DAM                                              1
   16          K1     FLOOD ROTING,OUTFLOW HYDROGRAPH AND OVERTOPPING ANALYSIS.
   17          Y                                    1
   18          Y1    1                                                -793.4     -1
   19          Y4 793.4   794.3   795.1   795.6   796.3   797.3   798.0   798.6   799.1.
   20          Y5    0.    10.0    50.0   100.0   200.0   400.0   600.0   800.0  1000.0
   21          SA  18.3    52.2    92.0   104.0   118.0
   22          SE 760.0   780.0   793.4   797.0   800.0
   23          SS 793.4
   24          SD 797.0     2.6     1.5
   25          SL    0.    90.0   170.0   540.0   730.0   950.0  1430.0  1750.0
   26          SV 797.0   797.5   798.0   798.5   799.0   799.5   800.0   800.5
   27          K    99
```

Input Data
Various PMF Events
Big Four Mine Dam
MO ID No 30729
B9

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**********************************
*HMRU HYDROGRAPH PACKAGE (HEC-1)
*DAM SAFETY VERSION      JULY 1978
*  LAST MODIFICATION   01 APR 80
**********************************

RUN DATE: 18 SEP 80
    TIME: 12.26.05
```

BIG FOUR MINE DAM NO. 30729
WOODWARD-CLYDE CONSULTANTS, HOUSTON, TEXAS JOB NO. 79CH009
PROBABLE MAXIMUM FLOW(PMF) RATIO ANALYSIS

JOB SPECIFICATION

NQ	NHR	NMIN	IDAY	IHR	IMIN	METRC	IPLT	IPRT	NSTAN
288	0	5	-0	-0	-0	-0	-0	-0	-0

JOPER	NWT	LKOPT	TRACE
5	-0	-0	-0

MULTI-PLAN ANALYSES TO BE PERFORMED
NPLAN= 1 NRTIO= 4 LRTIO= 1

RTIOS= .25 .50 .75 1.00

********** ********** ********** ********** **********

SUB-AREA RUNOFF COMPUTATION

INFLOW HYDROGRAPH CALCULATION

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
LAKE	0	-0	-0	-0	-0	1	-0	-0

HYDROGRAPH DATA

IHYDG	IUHG	TAREA	SNAP	TRSDA	TRSPC	RATIO	ISNOW	ISAME	LOCAL
1	2	.40	-0.	.40	1.00	-0.	-0	-0	-0

PRECIP DATA

SPFE	PMS	R6	R12	R24	R48	R72	R96
0.	26.00	102.00	120.00	130.00	-0.	-0.	-0.

LOSS DATA

LROPT	STRKR	DLTKR	RTIOL	ERAIN	STRKS	RTIOK	STRTL	CNSTL	ALSMX	RTIMP
-0	-0.	-0.	1.00	-0.	-0.	1.00	-1.00	-93.00	-0.	.40

CURVE NO = -93.00 WETNESS = -1.00 EFFECT CN = 93.00

UNIT HYDROGRAPH DATA
TC= -0. LAG= .40

RECESSION DATA
STRTQ= -1.00 QRCSN= -.05 RTIOR= 5.00

UNIT HYDROGRAPH 26 END OF PERIOD ORDINATES, TC= -0. HOURS, LAG= .40 VOL= 1.00

40.	124.	261.	389.	435.	425.	369.	293.	202.	148.
110.	82.	60.	44.	32.	23.	17.	13.	9.	7.
5.	4.	3.	2.	1.	0.				

Input Data
Various PMF Events
Big Four Mine Dam
MO ID No 30729
B10

END-OF-PERIOD FLOW

MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q	MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q
1.01	.05	1	.01	.01	.01	1.	1.01	12.05	145	.22	.22	.00	208.
1.01	.10	2	.01	.01	.01	1.	1.01	12.10	146	.22	.22	.00	228.
1.01	.15	3	.01	.01	.01	3.	1.01	12.15	147	.22	.22	.00	269.
1.01	.20	4	.01	.01	.01	5.	1.01	12.20	148	.22	.22	.00	329.
1.01	.25	5	.01	.01	.01	7.	1.01	12.25	149	.22	.22	.00	392.
1.01	.30	6	.01	.01	.01	10.	1.01	12.30	150	.22	.22	.00	458.
1.01	.35	7	.01	.01	.01	12.	1.01	12.35	151	.22	.22	.00	518.
1.01	.40	8	.01	.01	.01	14.	1.01	12.40	152	.22	.22	.00	561.
1.01	.45	9	.01	.01	.01	15.	1.01	12.45	153	.22	.22	.00	582.
1.01	.50	10	.01	.01	.01	16.	1.01	12.50	154	.22	.22	.00	618.
1.01	.55	11	.01	.01	.01	16.	1.01	12.55	155	.22	.22	.00	639.
1.01	1.00	12	.01	.01	.01	17.	1.01	13.00	156	.22	.22	.00	648.
1.01	1.05	13	.01	.01	.01	17.	1.01	13.05	157	.27	.26	.00	659.
1.01	1.10	14	.01	.01	.01	17.	1.01	13.10	158	.27	.26	.00	669.
1.01	1.15	15	.01	.01	.01	18.	1.01	13.15	159	.27	.26	.00	688.
1.01	1.20	16	.01	.01	.01	18.	1.01	13.20	160	.27	.26	.00	707.
1.01	1.25	17	.01	.01	.01	19.	1.01	13.25	161	.27	.26	.00	725.
1.01	1.30	18	.01	.01	.01	20.	1.01	13.30	162	.27	.26	.00	750.
1.01	1.35	19	.01	.01	.01	20.	1.01	13.35	163	.27	.26	.00	768.
1.01	1.40	20	.01	.01	.01	21.	1.01	13.40	164	.27	.26	.00	782.
1.01	1.45	21	.01	.01	.01	22.	1.01	13.45	165	.27	.26	.00	792.
1.01	1.50	22	.01	.01	.01	23.	1.01	13.50	166	.27	.26	.00	799.
1.01	1.55	23	.01	.01	.01	23.	1.01	13.55	167	.27	.26	.00	804.
1.01	2.00	24	.01	.01	.01	24.	1.01	14.00	168	.27	.26	.00	808.
1.01	2.05	25	.01	.01	.01	25.	1.01	14.05	169	.33	.33	.00	814.
1.01	2.10	26	.01	.01	.01	25.	1.01	14.10	170	.33	.33	.00	824.
1.01	2.15	27	.01	.01	.01	26.	1.01	14.15	171	.33	.33	.00	843.
1.01	2.20	28	.01	.01	.00	26.	1.01	14.20	172	.33	.33	.00	870.
1.01	2.25	29	.01	.01	.00	27.	1.01	14.25	173	.33	.33	.00	899.
1.01	2.30	30	.01	.01	.00	28.	1.01	14.30	174	.33	.33	.00	928.
1.01	2.35	31	.01	.01	.00	28.	1.01	14.35	175	.33	.33	.00	953.
1.01	2.40	32	.01	.01	.00	29.	1.01	14.40	176	.33	.33	.00	973.
1.01	2.45	33	.01	.01	.00	29.	1.01	14.45	177	.33	.33	.00	987.
1.01	2.50	34	.01	.01	.00	29.	1.01	14.50	178	.33	.33	.00	997.
1.01	2.55	35	.01	.01	.00	30.	1.01	14.55	179	.33	.33	.00	1004.
1.01	3.00	36	.01	.01	.00	30.	1.01	15.00	180	.33	.33	.00	1010.
1.01	3.05	37	.01	.01	.00	31.	1.01	15.05	181	.20	.20	.00	1009.
1.01	3.10	38	.01	.01	.00	31.	1.01	15.10	182	.40	.40	.00	1004.
1.01	3.15	39	.01	.01	.00	31.	1.01	15.15	183	.40	.40	.00	997.
1.01	3.20	40	.01	.01	.00	32.	1.01	15.20	184	.60	.60	.00	1009.
1.01	3.25	41	.01	.01	.00	32.	1.01	15.25	185	.70	.70	.00	1060.
1.01	3.30	42	.01	.01	.00	32.	1.01	15.30	186	1.71	1.71	.00	1159.
1.01	3.35	43	.01	.01	.00	33.	1.01	15.35	187	2.82	2.82	.00	1511.
1.01	3.40	44	.01	.01	.00	33.	1.01	15.40	188	1.11	1.11	.00	2004.
1.01	3.45	45	.01	.01	.00	33.	1.01	15.45	189	.71	.71	.00	2019.
1.01	3.50	46	.01	.01	.00	34.	1.01	15.50	190	.60	.60	.00	3119.
1.01	3.55	47	.01	.01	.00	34.	1.01	15.55	191	.40	.40	.00	3330.
1.01	4.00	48	.01	.01	.00	34.	1.01	16.00	192	.40	.40	.00	3329.
1.01	4.05	49	.01	.01	.00	34.	1.01	16.05	193	.31	.31	.00	3094.
1.01	4.10	50	.01	.01	.00	35.	1.01	16.10	194	.31	.31	.00	2729.
1.01	4.15	51	.01	.01	.00	35.	1.01	16.15	195	.31	.31	.00	2330.
1.01	4.20	52	.01	.01	.00	35.	1.01	16.20	196	.31	.31	.00	2000.
1.01	4.25	53	.01	.01	.00	35.	1.01	16.25	197	.31	.31	.00	1790.
1.01	4.30	54	.01	.01	.00	36.	1.01	16.30	198	.31	.31	.00	1640.
1.01	4.35	55	.01	.01	.00	36.	1.01	16.35	199	.31	.31	.00	1550.
1.01	4.40	56	.01	.01	.00	36.	1.01	16.40	200	.31	.31	.00	1279.
1.01	4.45	57	.01	.01	.00	36.	1.01	16.45	201	.31	.31	.00	1150.
1.01	4.50	58	.01	.01	.00	36.	1.01	16.50	202	.31	.31	.00	1129.

Input Data
Various PMF Events
Big Four Mine Dam
MO ID No 30729

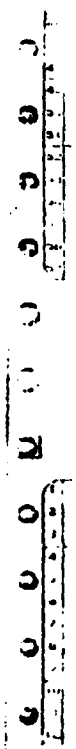
B11

1.01	4.55	57	.01	.01	.00	36.
1.01	4.50	58	.01	.01	.00	36.
1.01	4.55	59	.01	.01	.00	36.
1.01	5.00	60	.01	.01	.00	37.
1.01	5.05	61	.01	.01	.00	37.
1.01	5.10	62	.01	.01	.00	37.
1.01	5.15	63	.01	.01	.00	37.
1.01	5.20	64	.01	.01	.00	37.
1.01	5.25	65	.01	.01	.00	37.
1.01	5.30	66	.01	.01	.00	38.
1.01	5.35	67	.01	.01	.00	38.
1.01	5.40	68	.01	.01	.00	38.
1.01	5.45	69	.01	.01	.00	38.
1.01	5.50	70	.01	.01	.00	38.
1.01	5.55	71	.01	.01	.00	38.
1.01	6.00	72	.01	.01	.00	38.
1.01	6.05	73	.07	.06	.01	40.
1.01	6.10	74	.07	.06	.01	46.
1.01	6.15	75	.07	.06	.01	58.
1.01	6.20	76	.07	.06	.01	75.
1.01	6.25	77	.07	.06	.01	95.
1.01	6.30	78	.07	.06	.01	115.
1.01	6.35	79	.07	.06	.01	132.
1.01	6.40	80	.07	.06	.00	146.
1.01	6.45	81	.07	.06	.00	156.
1.01	6.50	82	.07	.06	.00	164.
1.01	6.55	83	.07	.06	.00	170.
1.01	7.00	84	.07	.06	.00	174.
1.01	7.05	85	.07	.06	.00	178.
1.01	7.10	86	.07	.06	.00	181.
1.01	7.15	87	.07	.06	.00	183.
1.01	7.20	88	.07	.06	.00	185.
1.01	7.25	89	.07	.06	.00	186.
1.01	7.30	90	.07	.06	.00	188.
1.01	7.35	91	.07	.06	.00	189.
1.01	7.40	92	.07	.06	.00	190.
1.01	7.45	93	.07	.06	.00	190.
1.01	7.50	94	.07	.06	.00	191.
1.01	7.55	95	.07	.06	.00	192.
1.01	8.00	96	.07	.06	.00	192.
1.01	8.05	97	.07	.06	.00	193.
1.01	8.10	98	.07	.06	.00	193.
1.01	8.15	99	.07	.06	.00	193.
1.01	8.20	100	.07	.06	.00	194.
1.01	8.25	101	.07	.06	.00	194.
1.01	8.30	102	.07	.06	.00	194.
1.01	8.35	103	.07	.06	.00	195.
1.01	8.40	104	.07	.06	.00	195.
1.01	8.45	105	.07	.06	.00	195.
1.01	8.50	106	.07	.06	.00	195.
1.01	8.55	107	.07	.06	.00	196.
1.01	9.00	108	.07	.06	.00	196.
1.01	9.05	109	.07	.06	.00	196.
1.01	9.10	110	.07	.06	.00	196.
1.01	9.15	111	.07	.06	.00	196.
1.01	9.20	112	.07	.06	.00	197.
1.01	9.25	113	.07	.06	.00	197.
1.01	9.30	114	.07	.06	.00	197.
1.01	9.35	115	.07	.06	.00	197.
1.01	9.40	116	.07	.06	.00	197.
1.01	9.45	117	.07	.06	.00	197.
1.01	9.50	118	.07	.06	.00	197.

1.01	16.45	201	.31	.31	.00	1128.
1.01	16.50	202	.31	.31	.00	1128.
1.01	16.55	203	.31	.31	.00	1083.
1.01	17.00	204	.31	.31	.00	1050.
1.01	17.05	205	.24	.24	.00	1023.
1.01	17.10	206	.24	.24	.00	997.
1.01	17.15	207	.24	.24	.00	967.
1.01	17.20	208	.24	.24	.00	932.
1.01	17.25	209	.24	.24	.00	899.
1.01	17.30	210	.24	.24	.00	868.
1.01	17.35	211	.24	.24	.00	839.
1.01	17.40	212	.24	.24	.00	808.
1.01	17.45	213	.24	.24	.00	792.
1.01	17.50	214	.24	.24	.00	781.
1.01	17.55	215	.24	.24	.00	773.
1.01	18.00	216	.24	.24	.00	767.
1.01	18.05	217	.02	.02	.00	754.
1.01	18.10	218	.02	.02	.00	724.
1.01	18.15	219	.02	.02	.00	664.
1.01	18.20	220	.02	.02	.00	577.
1.01	18.25	221	.02	.02	.00	480.
1.01	18.30	222	.02	.02	.00	389.
1.01	18.35	223	.02	.02	.00	303.
1.01	18.40	224	.02	.02	.00	237.
1.01	18.45	225	.02	.02	.00	192.
1.01	18.50	226	.02	.02	.00	161.
1.01	18.55	227	.02	.02	.00	137.
1.01	19.00	228	.02	.02	.00	117.
1.01	19.05	229	.02	.02	.00	103.
1.01	19.10	230	.02	.02	.00	92.
1.01	19.15	231	.02	.02	.00	86.
1.01	19.20	232	.02	.02	.00	81.
1.01	19.25	233	.02	.02	.00	77.
1.01	19.30	234	.02	.02	.00	74.
1.01	19.35	235	.02	.02	.00	72.
1.01	19.40	236	.02	.02	.00	71.
1.01	19.45	237	.02	.02	.00	69.
1.01	19.50	238	.02	.02	.00	69.
1.01	19.55	239	.02	.02	.00	68.
1.01	20.00	240	.02	.02	.00	67.
1.01	20.05	241	.02	.02	.00	67.
1.01	20.10	242	.02	.02	.00	67.
1.01	20.15	243	.02	.02	.00	67.
1.01	20.20	244	.02	.02	.00	67.
1.01	20.25	245	.02	.02	.00	67.
1.01	20.30	246	.02	.02	.00	67.
1.01	20.35	247	.02	.02	.00	67.
1.01	20.40	248	.02	.02	.00	67.
1.01	20.45	249	.02	.02	.00	67.
1.01	20.50	250	.02	.02	.00	67.
1.01	20.55	251	.02	.02	.00	67.
1.01	21.00	252	.02	.02	.00	67.
1.01	21.05	253	.02	.02	.00	67.
1.01	21.10	254	.02	.02	.00	67.
1.01	21.15	255	.02	.02	.00	67.
1.01	21.20	256	.02	.02	.00	67.
1.01	21.25	257	.02	.02	.00	67.
1.01	21.30	258	.02	.02	.00	67.
1.01	21.35	259	.02	.02	.00	67.
1.01	21.40	260	.02	.02	.00	67.
1.01	21.45	261	.02	.02	.00	67.
1.01	21.50	262	.02	.02	.00	67.
1.01	21.55	263	.02	.02	.00	67.

Input Data
Various PMF Events
Big Four Mine Dam
MO ID No 30729

B12



1.01	9.40	116	.07	.06	.00	197.	1.01	21.40	260	.02	.02	.00	67.
1.01	9.45	117	.07	.06	.00	197.	1.01	21.45	261	.02	.02	.00	67.
1.01	9.50	118	.07	.06	.00	197.	1.01	21.50	262	.02	.02	.00	67.
1.01	9.55	119	.07	.06	.00	197.	1.01	21.55	263	.02	.02	.00	67.
1.01	10.00	120	.07	.06	.00	198.	1.01	22.00	264	.02	.02	.00	67.
1.01	10.05	121	.07	.06	.00	198.	1.01	22.05	265	.02	.02	.00	67.
1.01	10.10	122	.07	.06	.00	198.	1.01	22.10	266	.02	.02	.00	67.
1.01	10.15	123	.07	.06	.00	198.	1.01	22.15	267	.02	.02	.00	67.
1.01	10.20	124	.07	.06	.00	198.	1.01	22.20	268	.02	.02	.00	67.
1.01	10.25	125	.07	.06	.00	198.	1.01	22.25	269	.02	.02	.00	67.
1.01	10.30	126	.07	.06	.00	198.	1.01	22.30	270	.02	.02	.00	67.
1.01	10.35	127	.07	.06	.00	198.	1.01	22.35	271	.02	.02	.00	67.
1.01	10.40	128	.07	.06	.00	198.	1.01	22.40	272	.02	.02	.00	67.
1.01	10.45	129	.07	.06	.00	198.	1.01	22.45	273	.02	.02	.00	67.
1.01	10.50	130	.07	.06	.00	198.	1.01	22.50	274	.02	.02	.00	67.
1.01	10.55	131	.07	.06	.00	199.	1.01	22.55	275	.02	.02	.00	67.
1.01	11.00	132	.07	.06	.00	199.	1.01	23.00	276	.02	.02	.00	67.
1.01	11.05	133	.07	.06	.00	199.	1.01	23.05	277	.02	.02	.00	67.
1.01	11.10	134	.07	.06	.00	199.	1.01	23.10	278	.02	.02	.00	67.
1.01	11.15	135	.07	.06	.00	199.	1.01	23.15	279	.02	.02	.00	67.
1.01	11.20	136	.07	.06	.00	199.	1.01	23.20	280	.02	.02	.00	67.
1.01	11.25	137	.07	.06	.00	199.	1.01	23.25	281	.02	.02	.00	67.
1.01	11.30	138	.07	.06	.00	199.	1.01	23.30	282	.02	.02	.00	67.
1.01	11.35	139	.07	.06	.00	199.	1.01	23.35	283	.02	.02	.00	67.
1.01	11.40	140	.07	.06	.00	199.	1.01	23.40	284	.02	.02	.00	67.
1.01	11.45	141	.07	.06	.00	199.	1.01	23.45	285	.02	.02	.00	67.
1.01	11.50	142	.07	.06	.00	199.	1.01	23.50	286	.02	.02	.00	67.
1.01	11.55	143	.07	.06	.00	199.	1.01	23.55	287	.02	.02	.00	67.
1.01	12.00	144	.07	.06	.00	199.	1.02	0.	288	.02	.02	.00	67.
									SUM	33.80	33.27	.53	10267.
										(859.1(	845.1(	14.1(	290?.?9(

Input Data
Various PMF Events
Big Four Mine Dam
MO ID NO 30729

B13

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

OPERATION	STATION	AREA	PLAN	RATIOS APPLIED TO FLOWS RATIO 1 .25	RATIO 2 .50	RATIO 3 .75	RATIO 4 1.00
HYDROGRAPH AT	LAKE	.40	1	839.	1678.	2517.	3356.
		(1.04)	(	23.76)(	47.51)(	71.27)(	95.03)(
ROUTED TO	DAM	.40	1	48.	215.	467.	924.
		(1.04)	(	1.35)(	6.09)(	13.21)(	26.18)(

SUMMARY OF DAM SAFETY ANALYSIS

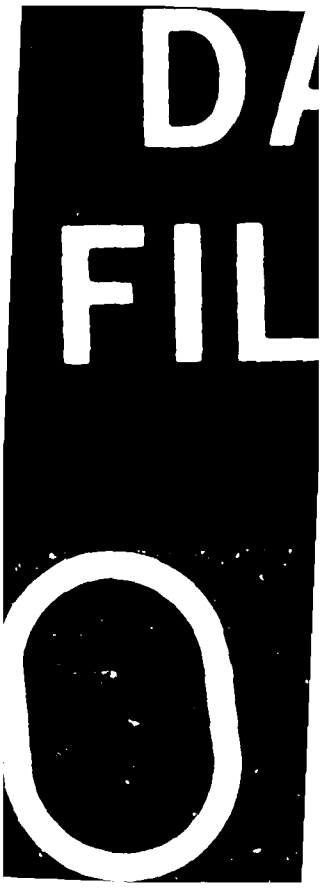
PLAN 1

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	793.40	793.40	797.00
STORAGE	1630.	1630.	1982.
OUTFLOW	0.	0.	340.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.25	795.05	0.	1786.	48.	0.	18.75	0.
.50	796.38	0.	1918.	215.	0.	18.50	0.
.75	797.44	.44	2028.	467.	3.83	18.25	0.
1.00	798.12	1.12	2101.	924.	5.83	17.33	0.

Output Summary
Various PMF Events
Big Four Mine Dam
MO ID No 30729

B14


DA
FIL